Name of research institute or organization:

Leibniz-Institut für Troposphärenforschung, Leipzig, Deutschland (IfT)

Title of project:

Sampling and physico-chemical characterization of ice nuclei in mixed phase clouds

Project leader and team:

Dr. Stephan Mertes, project leader
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Project description:

Ice nucleation in tropospheric, super-cooled clouds is the main initiation mechanism for precipitation in middle latitudes and moreover influences the radiative properties of the evolving mixed phase clouds. Heterogeneous ice nucleation that is induced by a special subset of atmospheric aerosol particles named ice nuclei plays the decisive role for ice particle formation in the middle and lower troposphere. But up to now, the physico-chemical properties of ice nuclei (size, number concentration, chemical composition) have been rather exclusively studied theoretically or in laboratory experiments but hardly inside real tropospheric clouds.

A sampling system based on the principle of a counterflow virtual impactor (CVI) has been developed (Ice-CVI) in order to characterize tropospheric ice nuclei that have formed ice particles in clouds. Inside mixed-phase clouds the Ice-CVI separates ice particles smaller than 20 µm by pre-segregating large ice crystals, super-cooled droplets and interstitial particles. The collected small ice particles remain airborne in the vertical sampling system and are completely sublimated in a dry and particle free carrier air stream. In this way, the contained non-volatile aerosol particles are released as dry residuals which can be analysed by instruments coupled to the Ice-CVI. The sampled small ice particles do not incorporate particles by riming or aerosol scavenging, i.e. the ice particle residuals can be considered as the original ice nuclei (IN).

The sampling properties of the novel Ice-CVI sampling system was successfully verified during the international field campaign CLACE-3 (cloud and aerosol characterization experiment) at the high alpine research station Jungfraujoch in winter 2004. After CLACE-4 (winter 2005), the Ice-CVI was again operated at the Jungfraujoch during the international joint field campaign CLACE-5 (February/March 2006) in order to carry out systematic measurements of IN. During this field experiment, which was led by the German collaborative research centre TROPEIS the Ice-CVI was coupled for the first time with single particle mass spectrometers (ATOFMS from ETH Zürich and SPLAT from the University of Mainz). Moreover, a new aerosol mass spectrometer (W-ToF-AMS from MPI Mainz) was connected. Further instrumentation for the characterization of IN was similar to CLACE-3 and CLACE-4. Number concentration and number size distribution of the ice nuclei were measured with a condensation particle counter (CPC, operated by IfT) and a combination of scanning mobility particle sizer and optical particle counter (SMPS and OPC, operated by the PSI, Villigen). By means of a filter-based particle soot absorption photometer (PSAP, IfT) the mass concentration of black carbon (BC) within the IN was determined. Two impactors were connected for the off-line single

particle analysis of the IN samples using environmental scanning electron microscopy (ESEM, Technical University of Darmstadt) and x-ray tomography and spectroscopy (University of Mainz). One Filter sampler was connected to take samples for off-line IN analysis with the static diffusion chamber FRIDGE (University of Frankfurt).

The sampling efficiency of the Ice-CVI system strongly depends on the wind speed at the inlet, which might be quite different from the Meteo-Swiss wind measurements carried out at another place of the Jungfraujoch station. Thus, a wind measurement system was placed close to inlet to determine the wind conditions for the ice particle sampling which are shown in Fig.1.

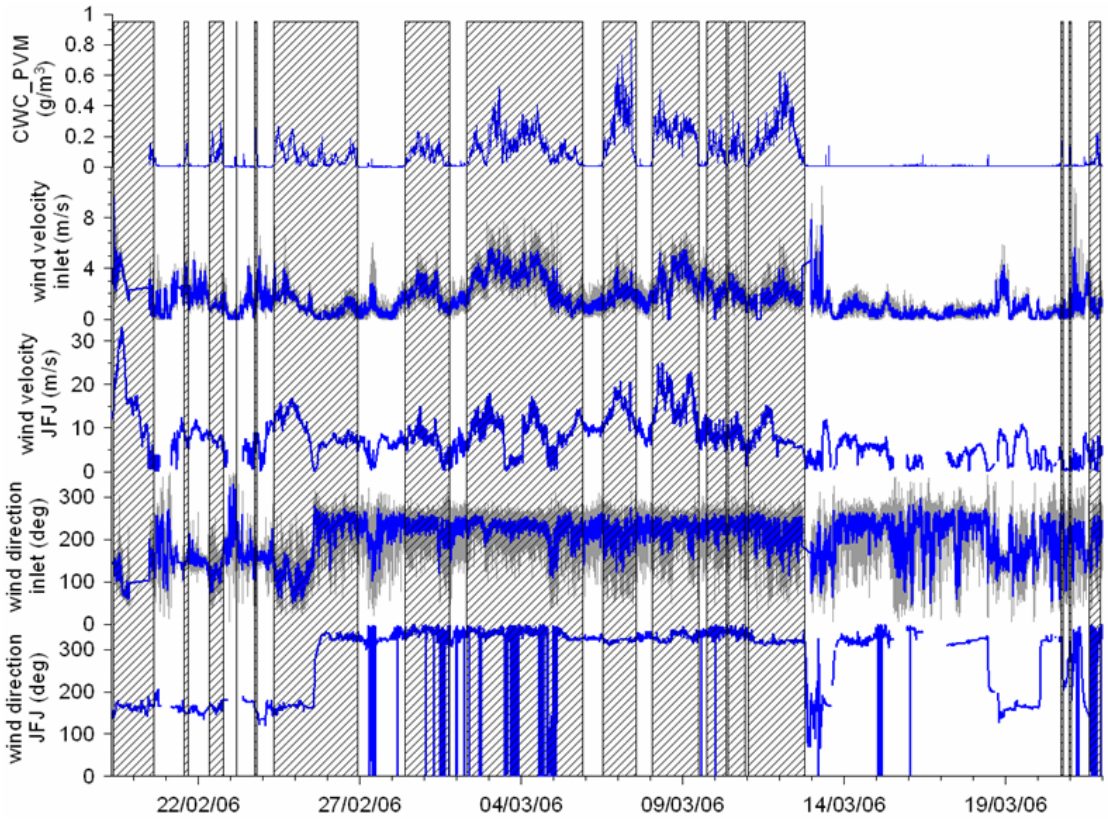

Fig.1 Wind velocity and direction measured at the Ice-CVI inlet in comparison to Meteo Swiss information. The condensed water content (CWC) denotes the periods of cloud events marked by the dashed boxes.

From Fig.1 it is obvious that beside a small shift in wind direction when the wind is coming from north-west, there is a substantial reduction of wind velocity at the Ice-CVI inlet compared to the prevailing wind. This is most likely due to the position of the inlet platform at the Sphinx building. As a consequence, the Ice-CVI sampling efficiency is close to one for ice particle sizes up to 20 µm, which is important for a quantitative analysis of the sampled ice nuclei.

Microphysical properties of IN already observed during CLACE-3 and CLACE-4 could verified in 2006. This includes low concentrations with maxima of several IN cm^{-3} and a substantially increased IN fraction of the total aerosol for increasing particle sizes (cf. activity reports 2004 and 2005). Moreover, information about the chemical IN composition obtained in the former CLACE campaigns was also observed again in the actual measurements. With respect to particle mass non-refractory matter, i.e. mineral dust, black carbon and low volatile organics were found as IN components. This was affirmed during CLACE-5, but now with respect to

number, which is much more meaningful, by means of the single particle mass spectrometers coupled to the Ice-CVI. From all detected IN, 60 % and 10 % were attributed to mineral dust and black carbon particles, respectively.

Thus, the data base of ice nuclei measurements could be significantly improved during CLACE-5 in 2006 still implying an anthropogenic influence on ice nucleation in tropospheric supercooled clouds.

Key words:

aerosol cloud interactions, mixed-phase clouds, heterogeneous ice nucleation, ice nuclei

Internet data bases:

http://www.tropos.de

Collaborating partners/networks:

Paul Scherrer Institute Villigen; ETH Zurich; Max-Planck Institute Mainz; University of Mainz; Technical University of Darmstadt; University of Frankfurt

Scientific publications and public outreach 2006:

Refereed journal articles

Cozic, J., B. Verheggen, S. Mertes, P. Connolly, K.N. Bower, A. Petzold, U. Baltensperger, and E. Weingartner, Scavenging of black carbon in mixed phase clouds at the high alpine site Jungfraujoch, Atmos. Chem. Phys. Discuss., accepted, 2006.

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Conference papers

Mertes, S., B. Verheggen, S. Walter, M. Ebert, P. Connolly, J. Schneider, K.N. Bower, J. Cozic, A. Worringen, and E. Weingartner, Physico-chemical characterization of ice particle residuals in tropospheric mixed-phase clouds, 12th Conference on Cloud Physics, American Meteorological Society, Madison, WI, USA, July 10-14, 2006.

Mertes, S., B. Verheggen, S. Walter, S., M. Ebert, P. Connolly, J. Schneider, K.N. Bower, J. Cozic, A. Worringen, and E. Weingartner, Counterflow Virtual Impactor

based collection of small ice particles in mixed-phase clouds for the physico-chemical characterization of tropospheric ice nuclei, 7th International Aerosol Conference, American Association for Aerosol Research (AAAR), St. Paul, MN, USA, September 10-15, 2006.

Data books and reports

Mertes, S., Field Investigations of Aerosol-Cloud Interactions based on the Counterflow Virtual Impactor Technique, Atmosphärisch-Chemisches Kolloquium des Instituts für Chemie und Dynamik der Geosphäre (ICG), Forschungszentrum Jülich, Germany.

Mertes, S., Sammlung kleiner Eispartikel zur physiko-chemischen Charakterisierung troposphärischer Eiskeime mithilfe der Counterflow Virtual Impactor Technik, 8. Mitgliederversammlung des SFB 641 TROPEIS, Mainz, Deutschland.

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